European Commission

Joint Research Centre

Introduction to the Gamma Spectrum Generator

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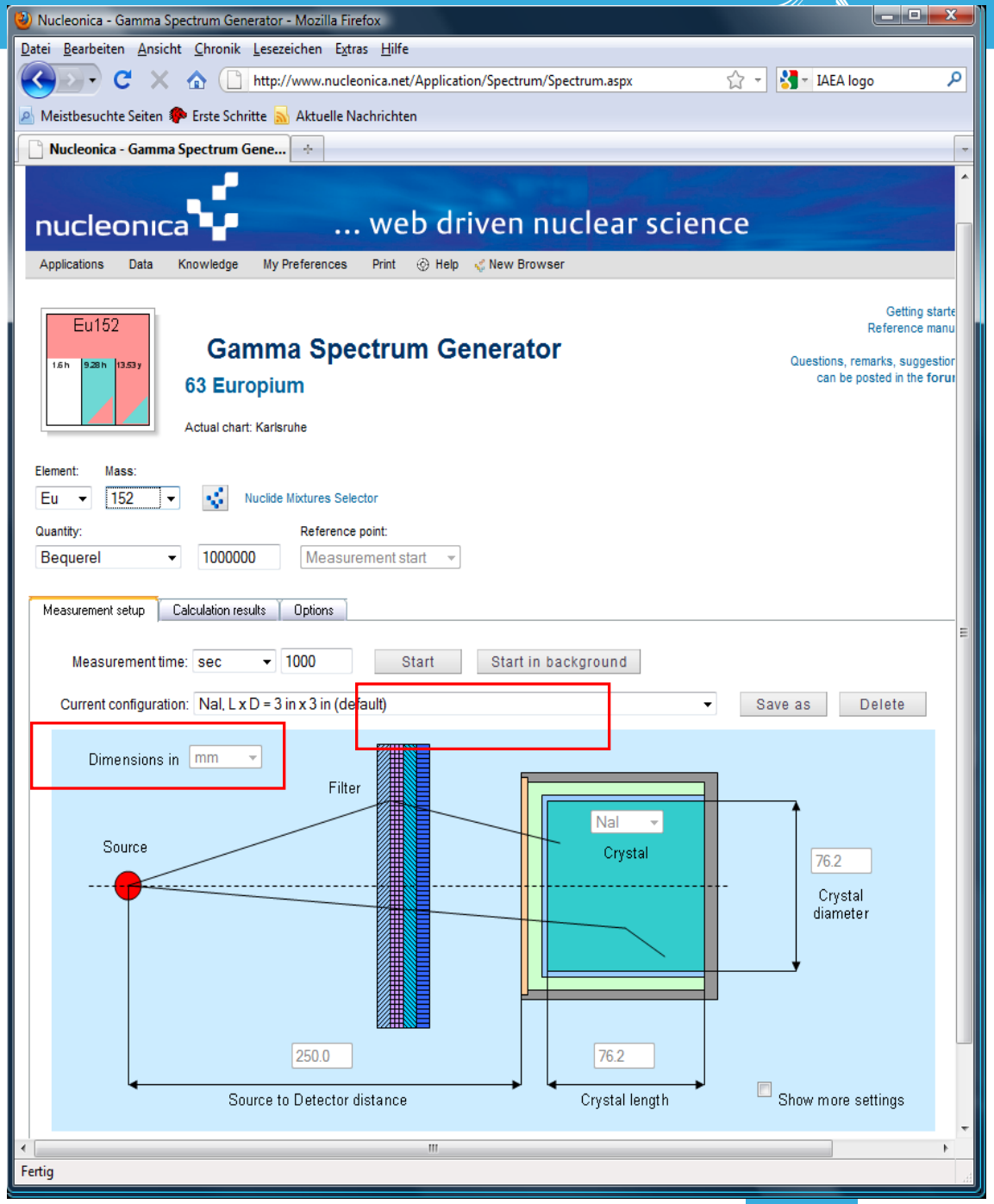


How to get to the GSG page:

1. Select Applications->Gamma Spectrum Generator from the Nucleonica's main menu

OR

2. Go to the Nuclear Science Applications Portal and select Gamma Spectrum Generator from the application list

Presentation outline

GSG in basic mode

- Modeling approach
- Introduction to the GSG features
- Experimental validation of the GSG

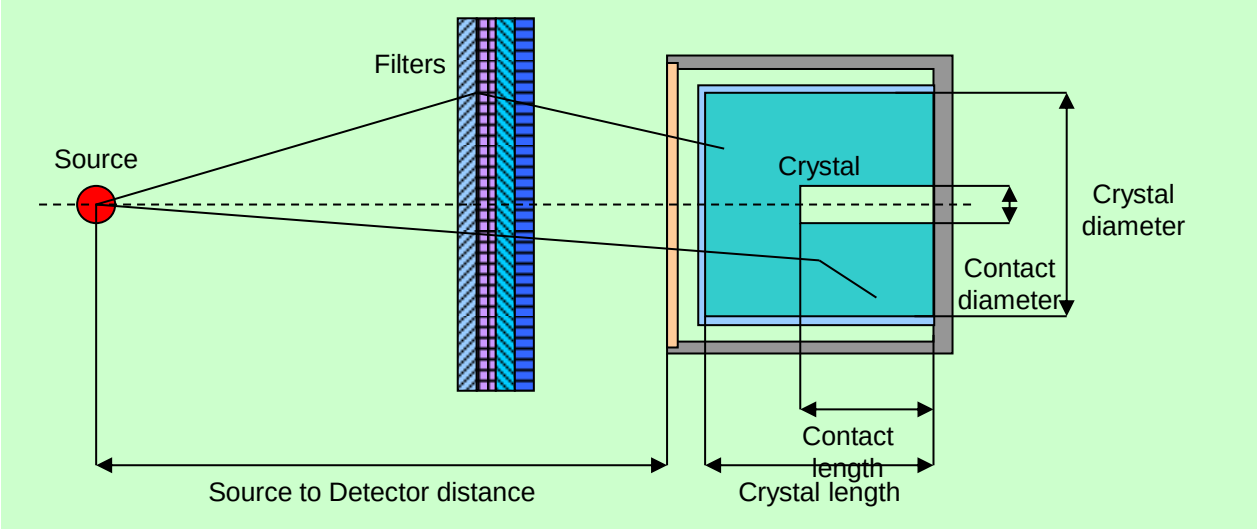
GSG-PRO

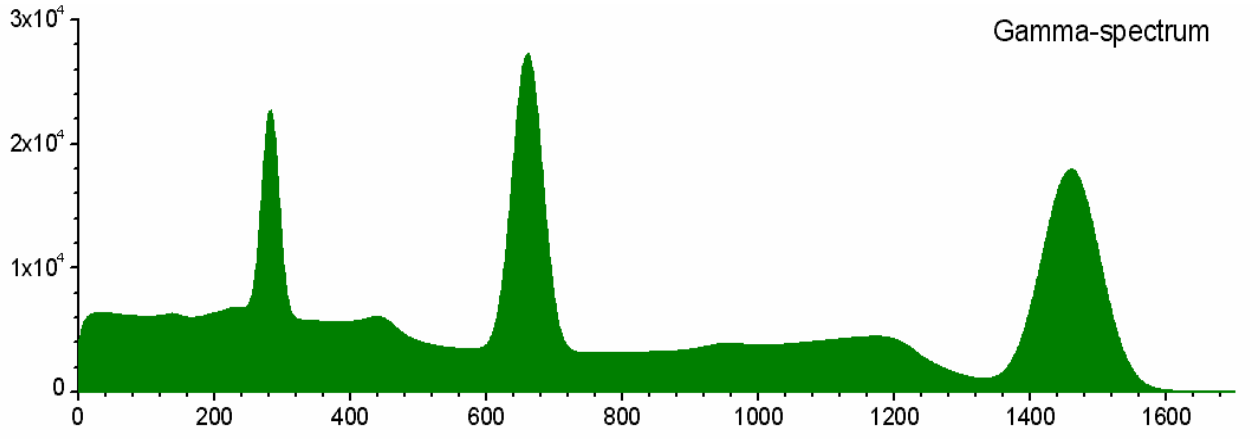
- Additional modeling features

Exercises

GSG in basic mode: Modeling approach

Measurement setup model implemented:





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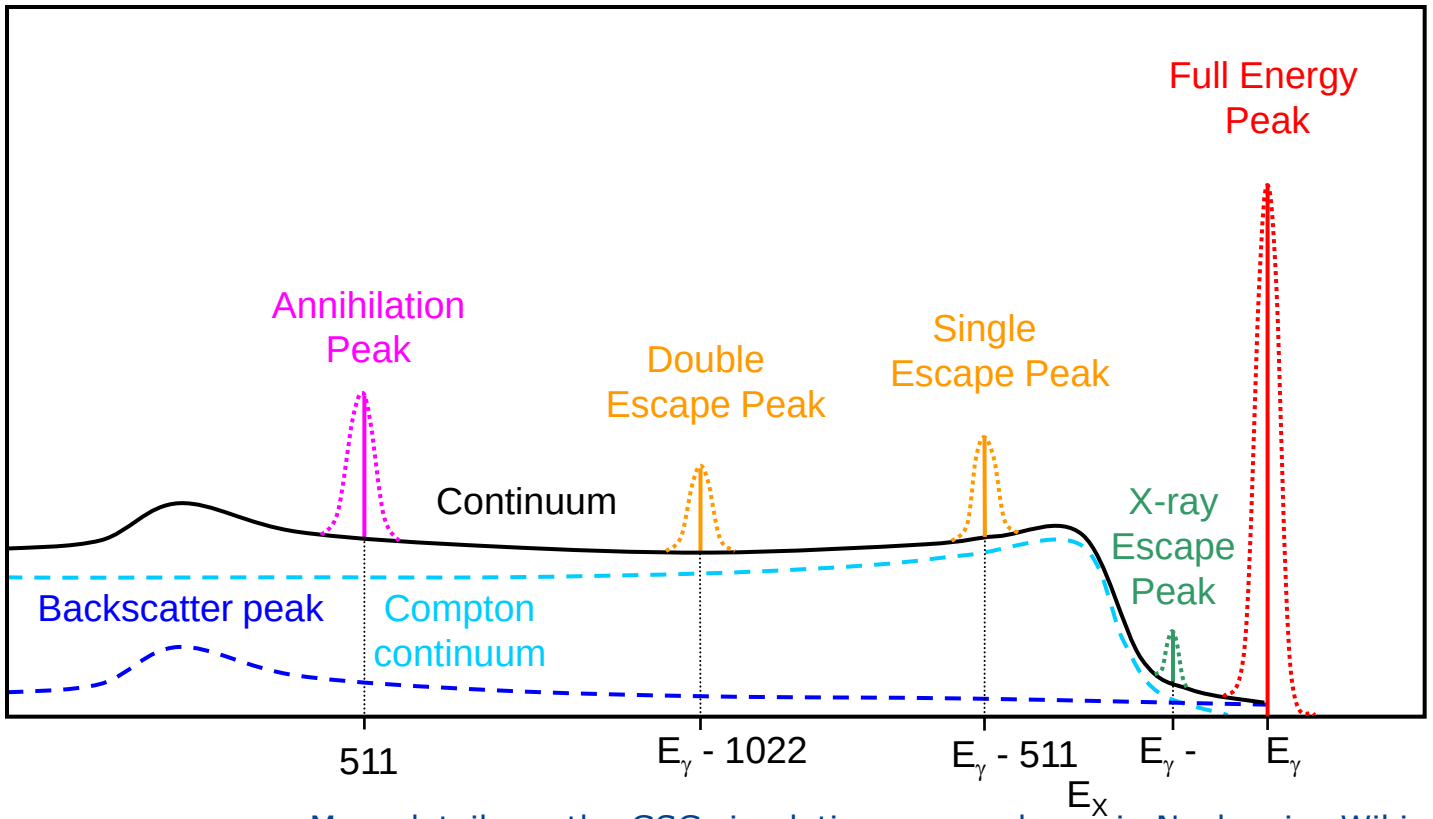
GSG in basic mode: Modeling approach

- For spectrum modeling the GSG uses a comprehensive database of detector responses for gamma-ray energies from 10 keV to 10 MeV, which were obtained using extensive Monte Carlo simulations



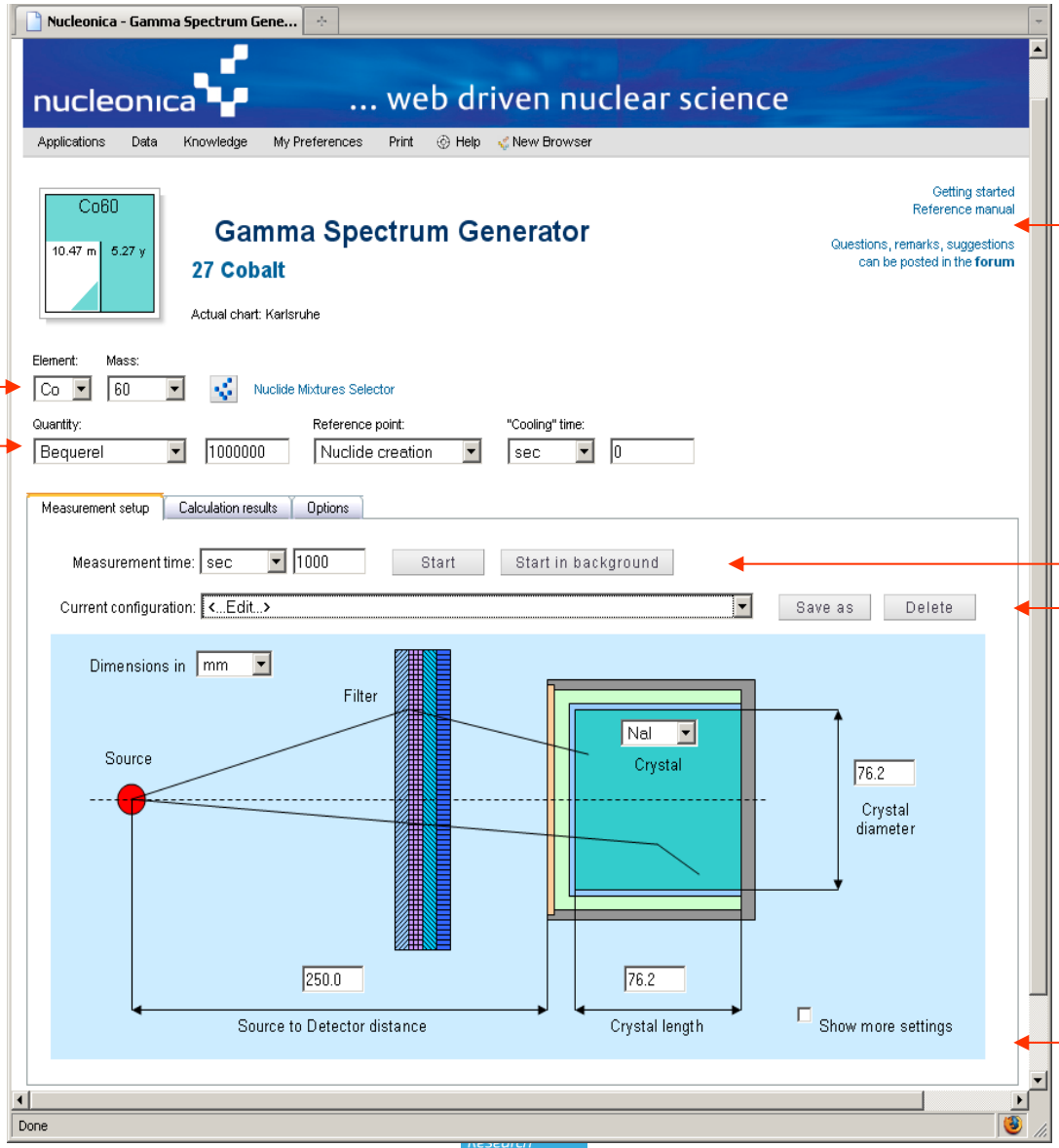
- More details on the GSG simulation approach see in Nucleonica Wiki at http://www.nucleonica.net/wiki/index.php/Help:Gamma_Spectrum_Generator

GSG in basic mode: GSG features

Select an arbitrary individual nuclide or a pre-defined mixture of nuclides as a radiation source

Specify the quantity (activity, mass, number of atoms, dose rate) of a nuclide or a mixture either
- at the spectrum measurement starting point of time, or
- at the moment of nuclide/mixture creation.

In the last case, the controls for specifying duration of a source "cooling" time interval become available.



Links to the quick start and detailed reference manuals, as well as to the GSG user's forum

Press "Start" button to start a simulation

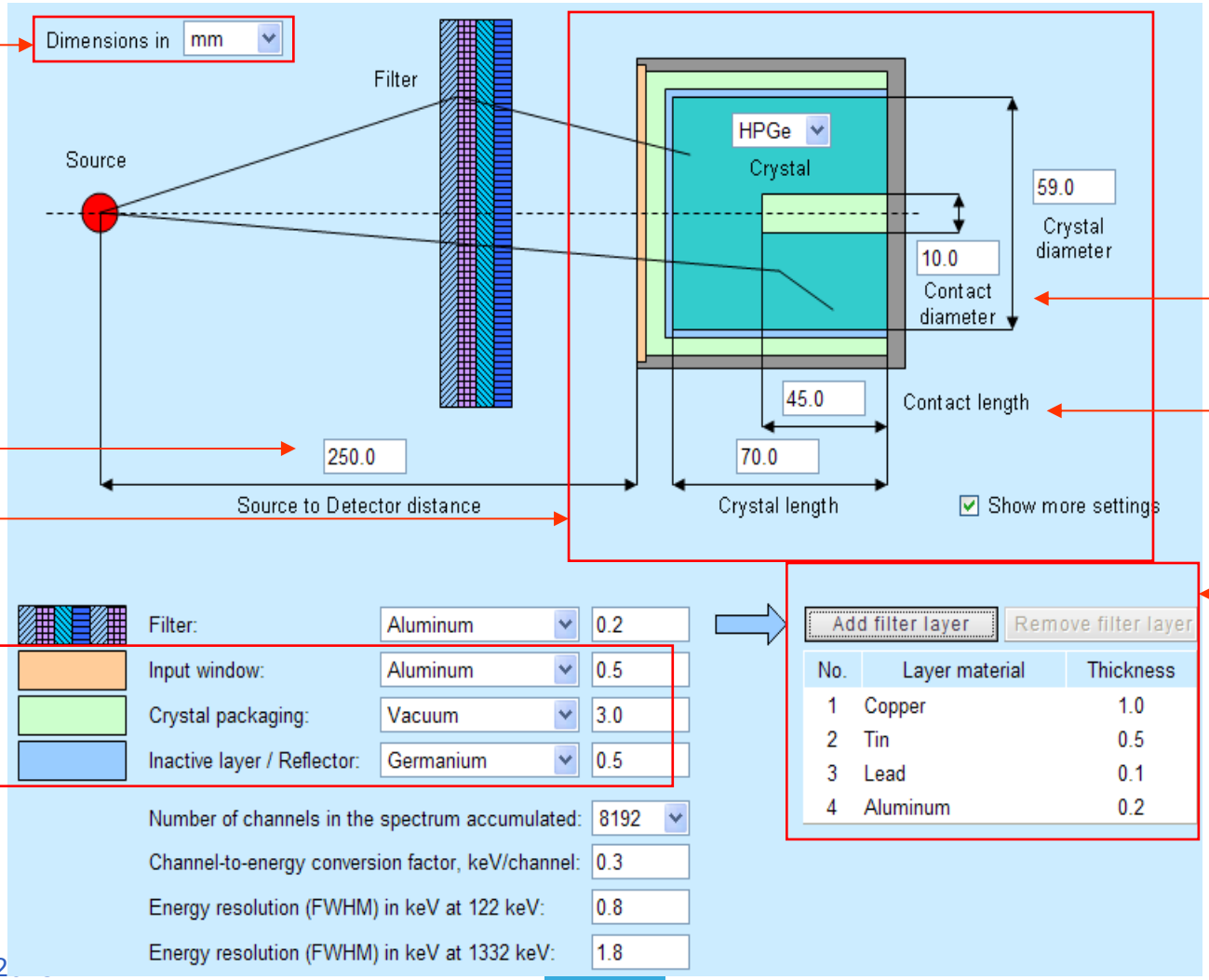
- Choose a suitable γ-spectrometer from 6 pre-defined configurations, including HPGe and NaI detectors, or
- Select "Edit" to create a new spectrometer.

Tick the checkbox to get access to additional spectrometer settings

GSG in basic mode: GSG features

Configuring a new spectrometer:

Dimensions can be entered in “mm”, “cm” or “inch” units



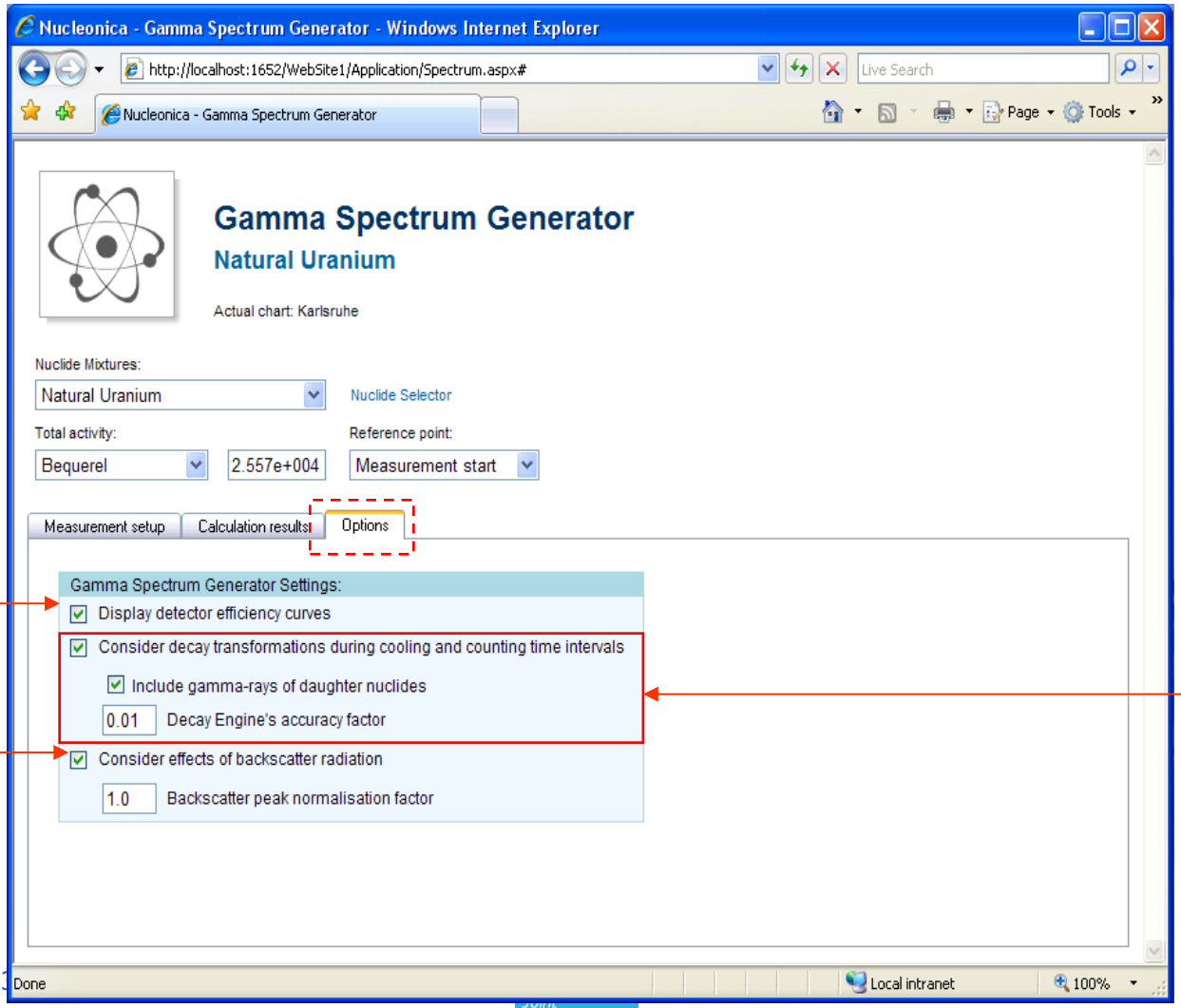
The dimensions of a cylindrical contact at the rear side of the crystal (a construction feature of conventional coaxial HPGe detectors) can be specified

The configurable parameters include the source-to-detector distance, as well as dimensions and materials of the detector construction elements.

Up to 6 additional absorbing filters made of Al, Cu, Fe, Pb, Sn, or polyethylene can be placed between source and detector

GSG in basic mode: GSG features

Selecting calculation options:



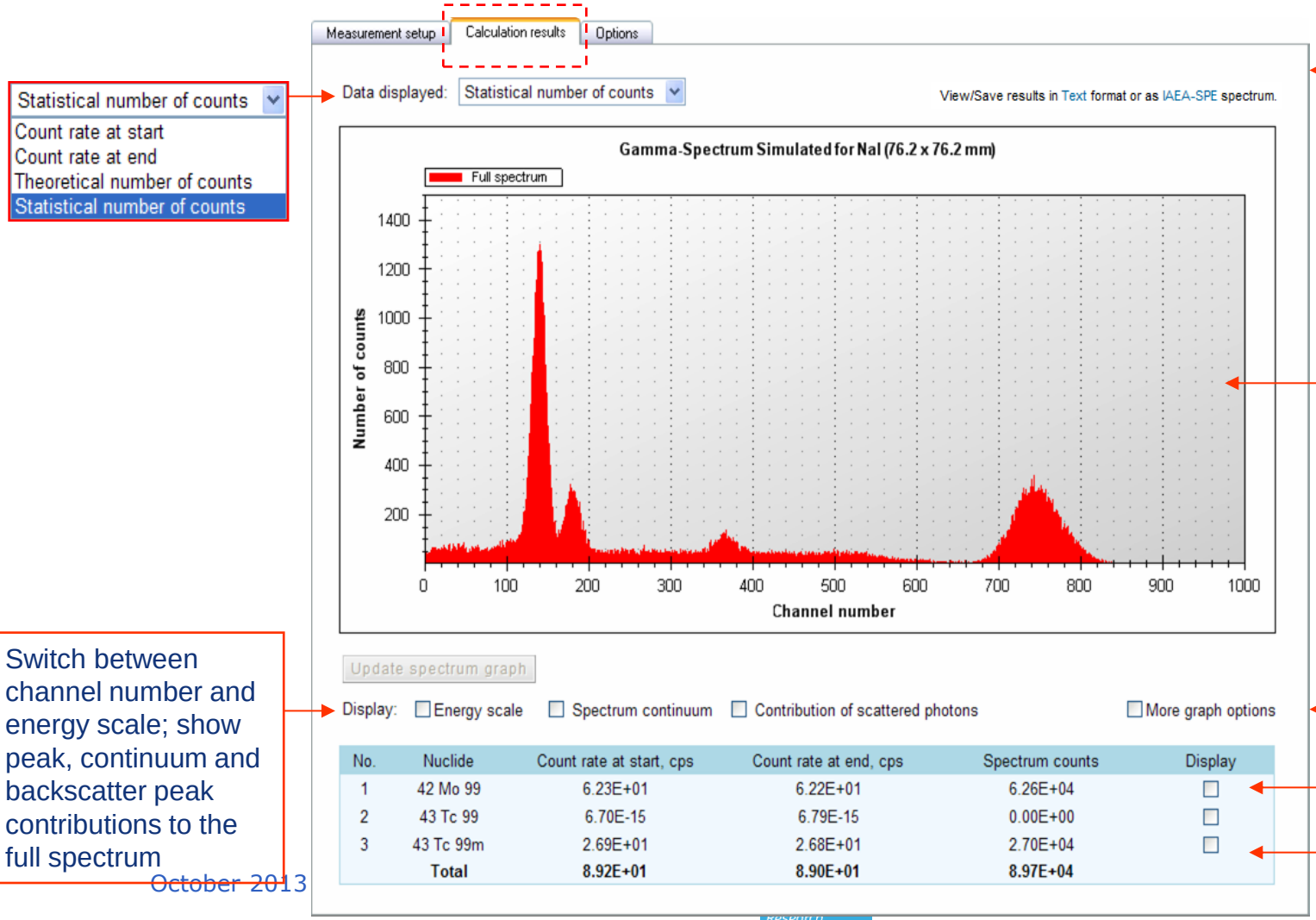
Efficiency Graph can be activated in the Calculation Results output

The backscatter peak simulation can be switched on/off, and its contribution to the spectrum can be adjusted

Decay calculations can be enabled that will allow contributions from decay products, being accumulated during source cooling and spectrum measurement time intervals

GSG in basic mode: GSG features

Exploring calculation results:



Spectral information can be saved as a text file as IAEA-SPE spectrum or Excel.

Right click within the graph area enables a context menu, from which one can print or download the spectrum graph

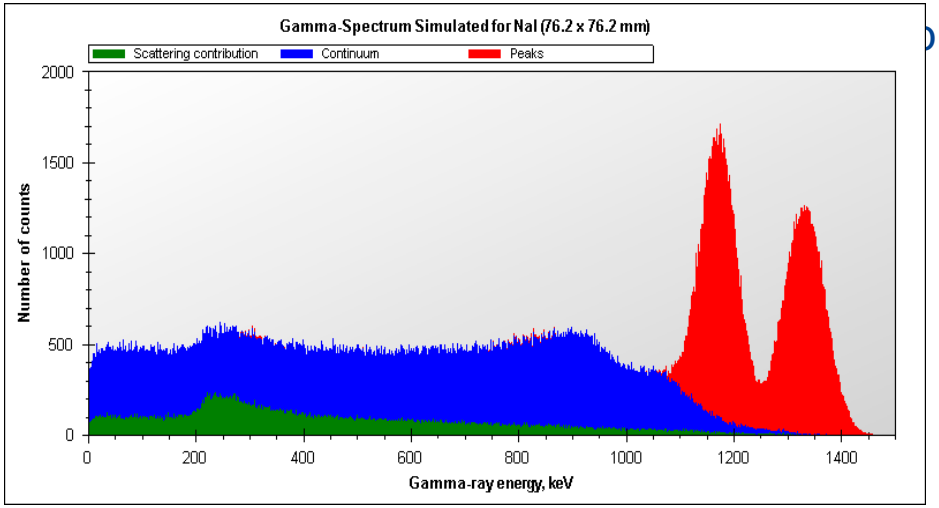
Additional options allow to customize appearance of the graph to meet one's needs and requirements

Display nuclide specific contributions to the full spectrum

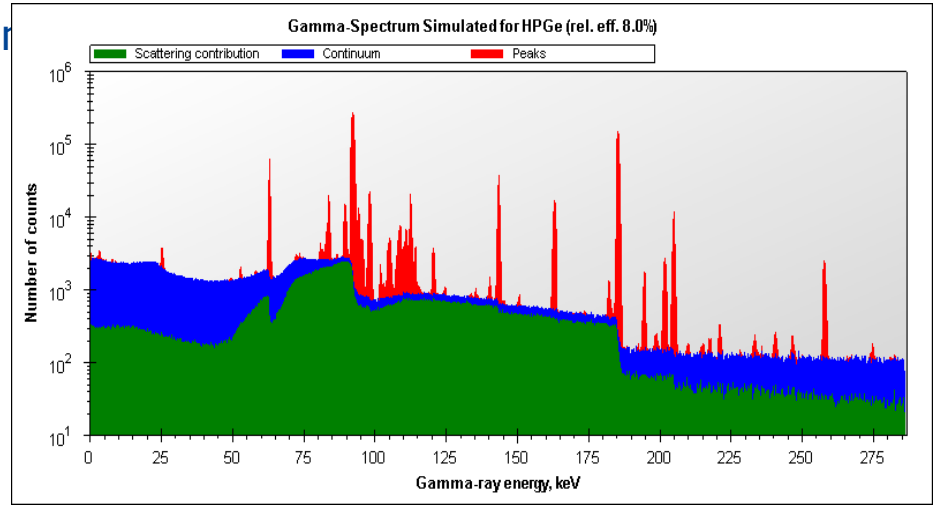
Switch between channel number and energy scale; show peak, continuum and backscatter peak contributions to the full spectrum

GSG in basic mode: GSG features

100 kBq ^{60}Co



1 g Nat U (2 years after separation)

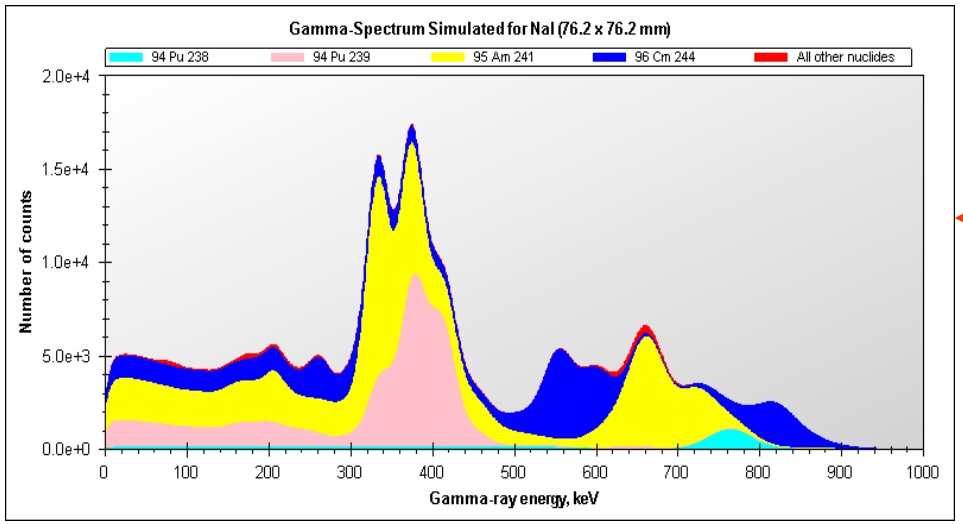


Detector - NaI (∅3″×3″)
Source-to-detector distance - 25 cm
Measurement time - 1000 s

Detector – LEGe (20 mm × 2800 mm^2)
Source-to-detector distance – 25 mm
Filter – 0.5 mm Sn
Measurement time - 10^5 s

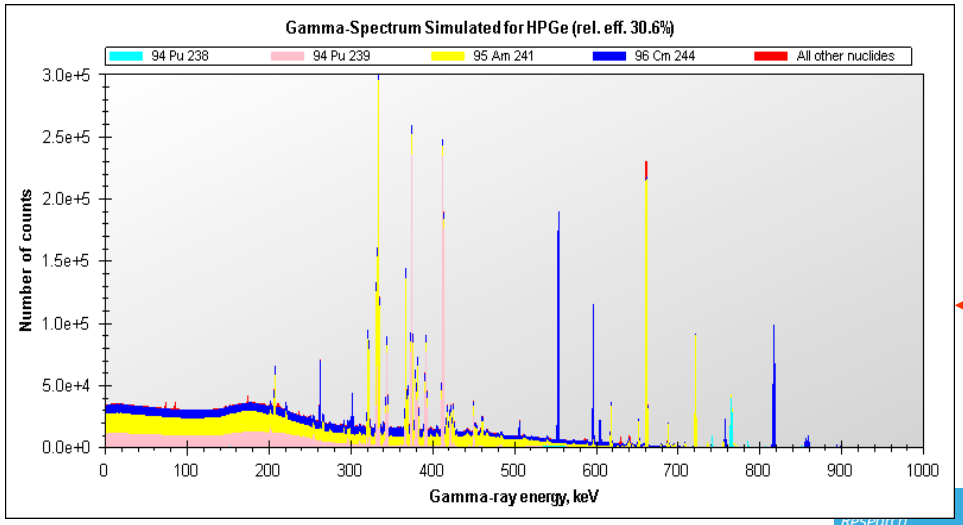
GSG in basic mode: GSG features

Displaying contributions of different nuclides:



Detector – NaI (∅3″×3″)
Source-to-detector distance – 25 cm
Filter – 5 mm Pb
Measurement time - 1000 s

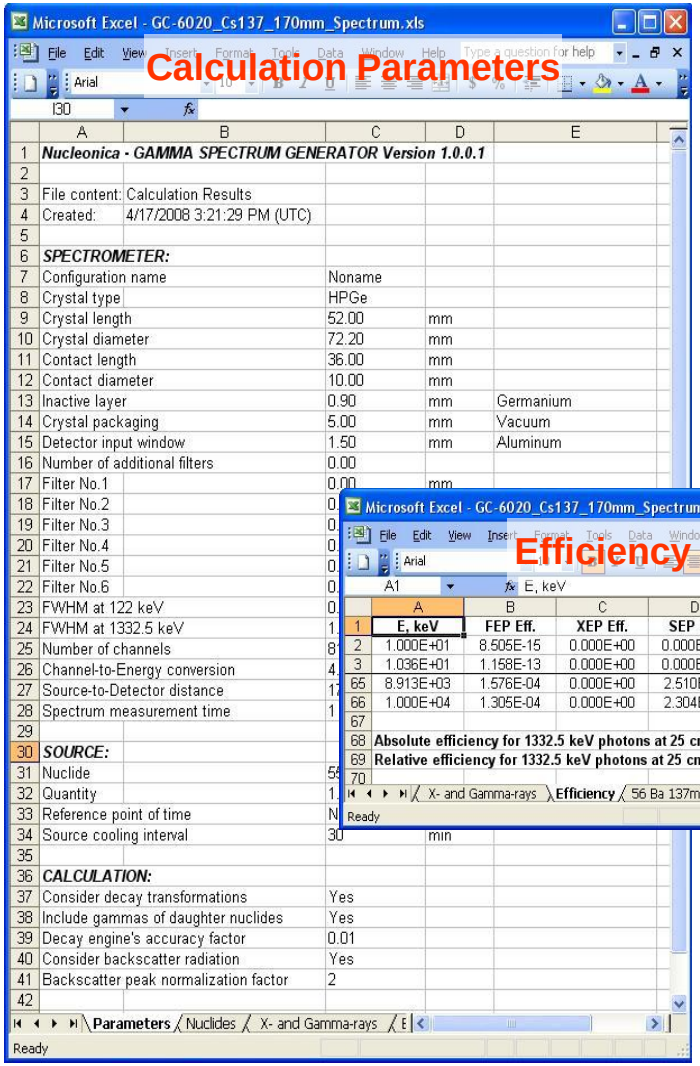
Actinides extracted from 1 kg 6-year-aged PWR spent fuel. Activity - 5.25 TBq

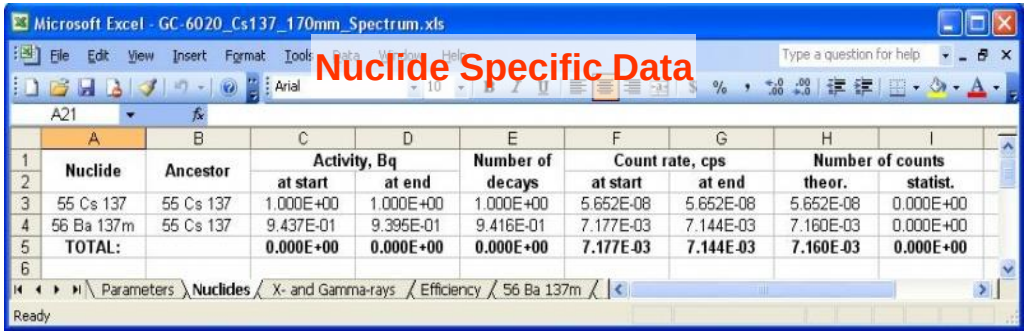


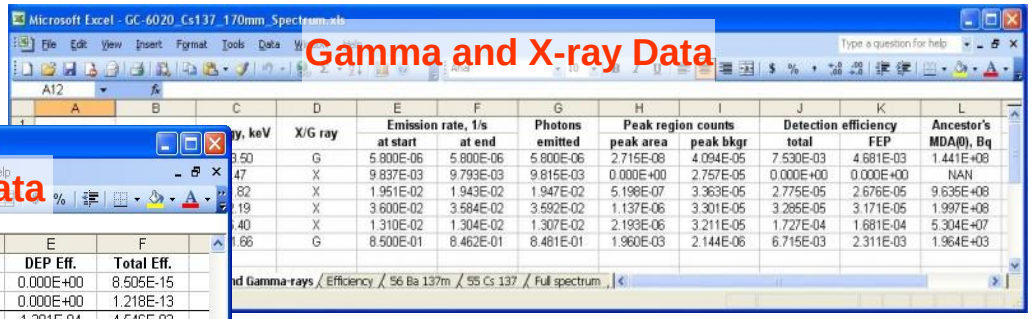
Detector – BEGe (30% rel. eff.)
Source-to-detector distance – 25 cm
Filter – 5 mm Pb
Measurement time - 1000 s

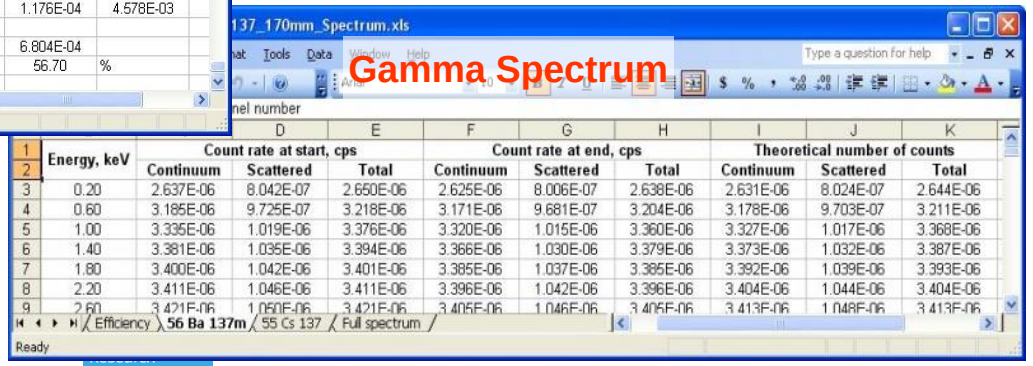
GSG in basic mode: GSG features

Saving calculation results in Text / Excel formats:



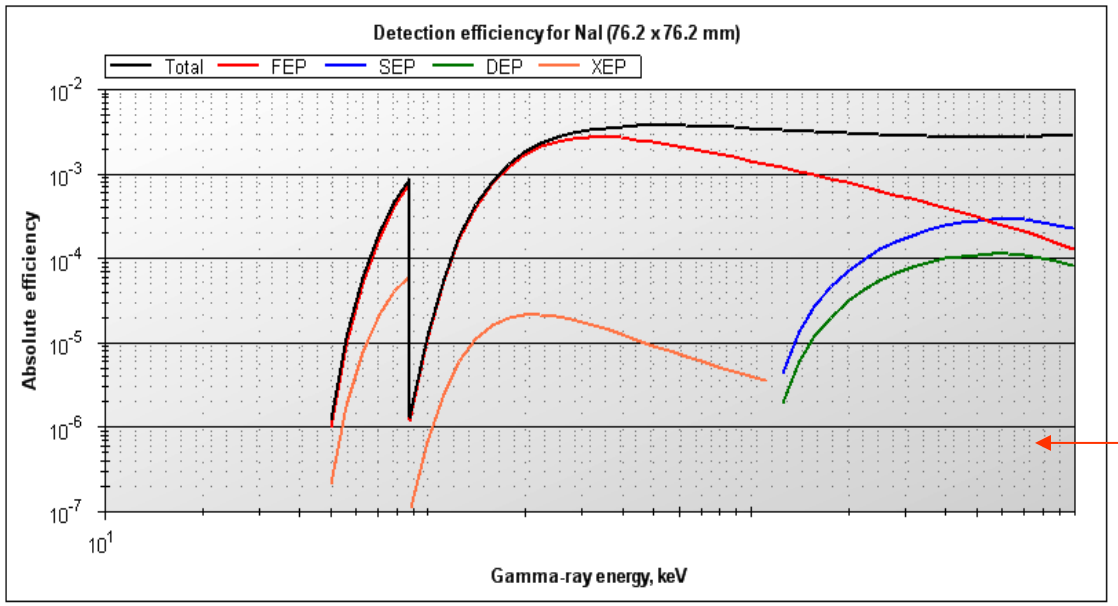






GSG in basic mode: GSG features

Plotting detection efficiencies:



Update efficiency graph

Efficiencies displayed: Full Energy Peak (FEP) Single Escape Peak (SEP) Total
X-ray Escape Peak (XEP) Double Escape Peak (DEP) More graph options

X-axis settings:

Scale: Auto Log; Minimum 10; Maximum 10000
Tick steps: Auto; Major step 1000; Substeps No 5
Grid lines: Major Minor
Ticks: In Out Labels

Y-axis settings:

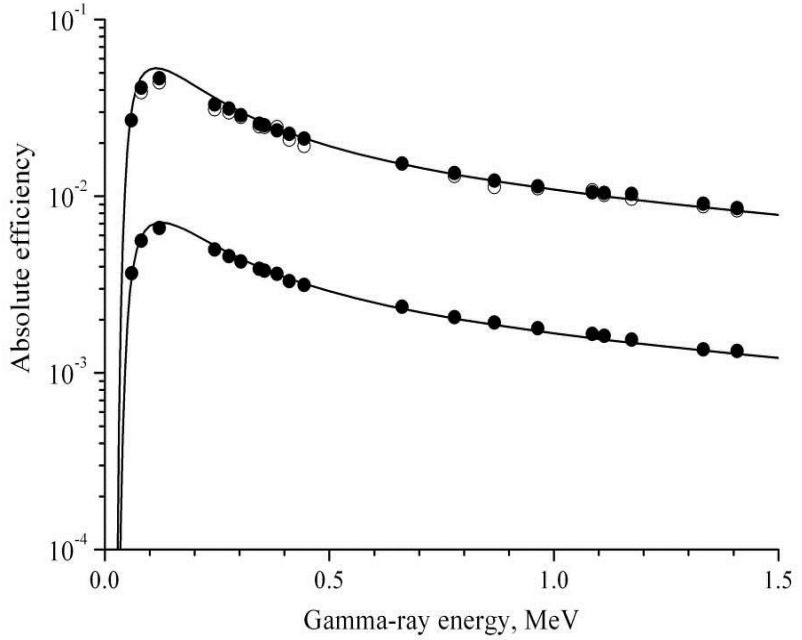
Scale: Auto Log; Minimum 0; Maximum 1.00
Tick steps: Auto; Major step 0.01; Substeps No 5
Grid lines: Major Minor
Ticks: In Out Labels

Right click within the graph area enables a context menu, from which one can print or download the efficiency graph

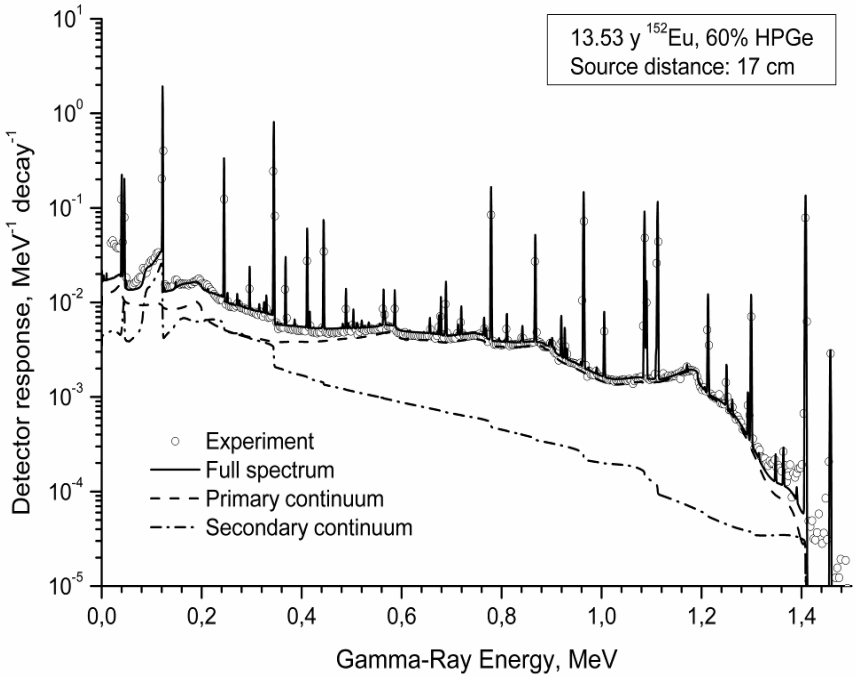
Select efficiency data to be displayed on the graph

Additional options allow to tailor the efficiency graph to one's needs and requirements

GSG in basic mode: Experimental validation (HPGe)



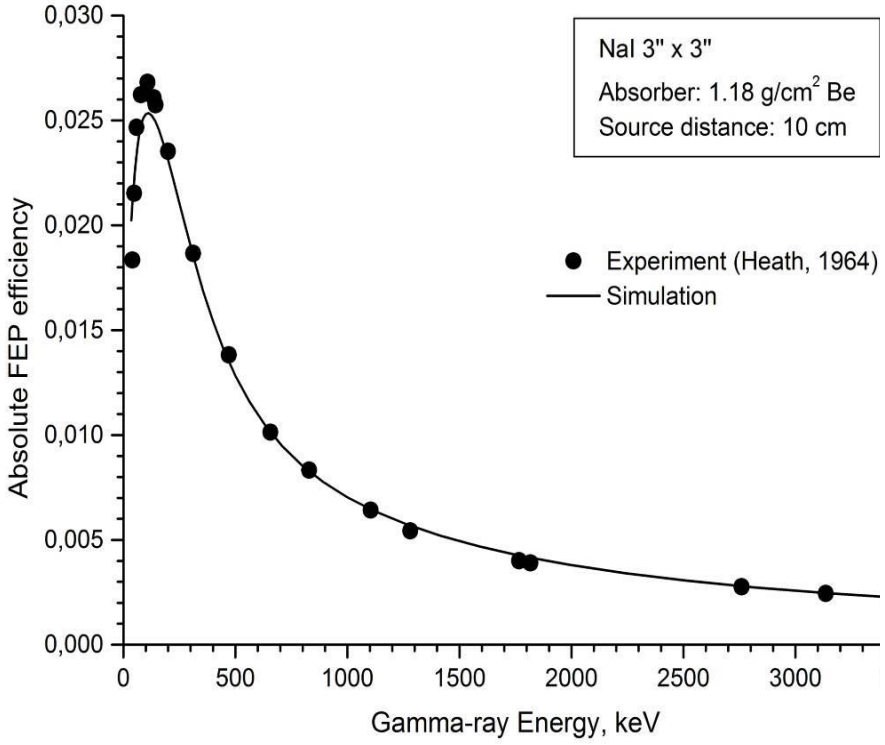
Full Energy Peak efficiency as a function of the photon energy: circles – experimental values, curve – calculated. Two sets of data refer to the source location at 5 cm and 17 cm distances from the detector end cap.



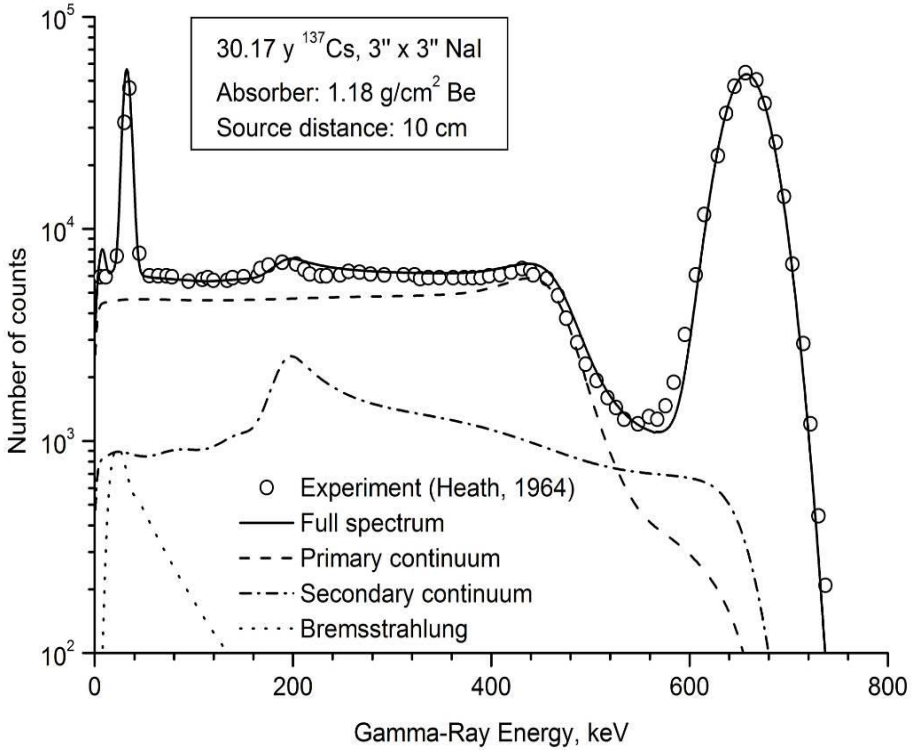
Calculated (curve) and experimental (circles) detector responses for ^{152}Eu source at 17 cm distance from the detector end cap.

GSG in basic mode: Experimental validation (NaI)

Results of the experimental validation with 3″ × 3″ NaI scintillation detector



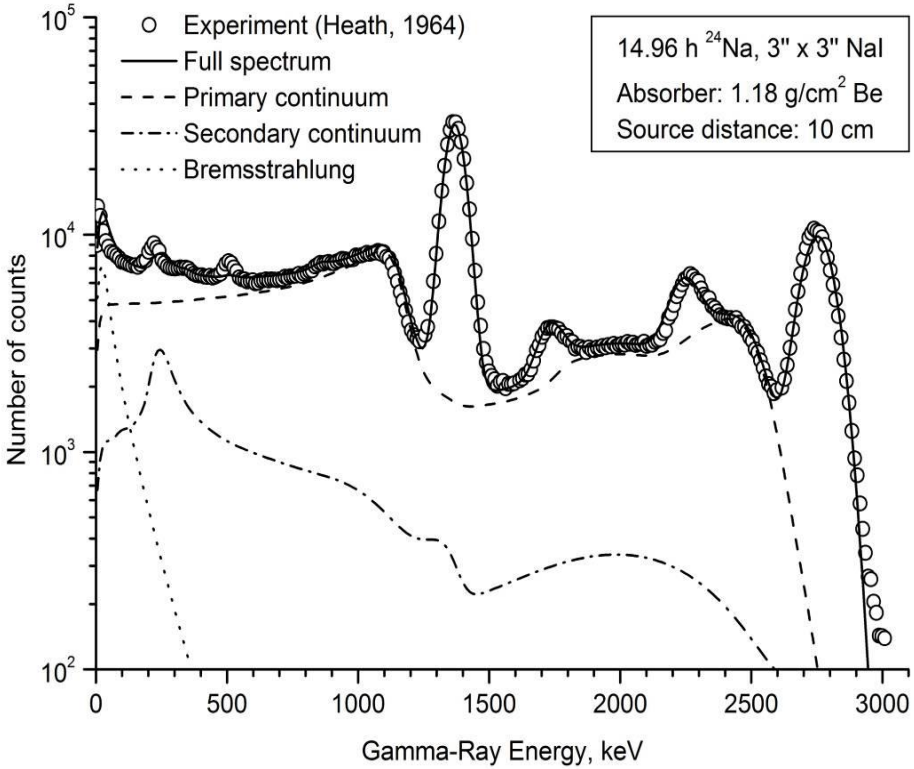
The simulated vs. experimental *FEP* efficiencies for a NaI 3″ × 3″ detector.



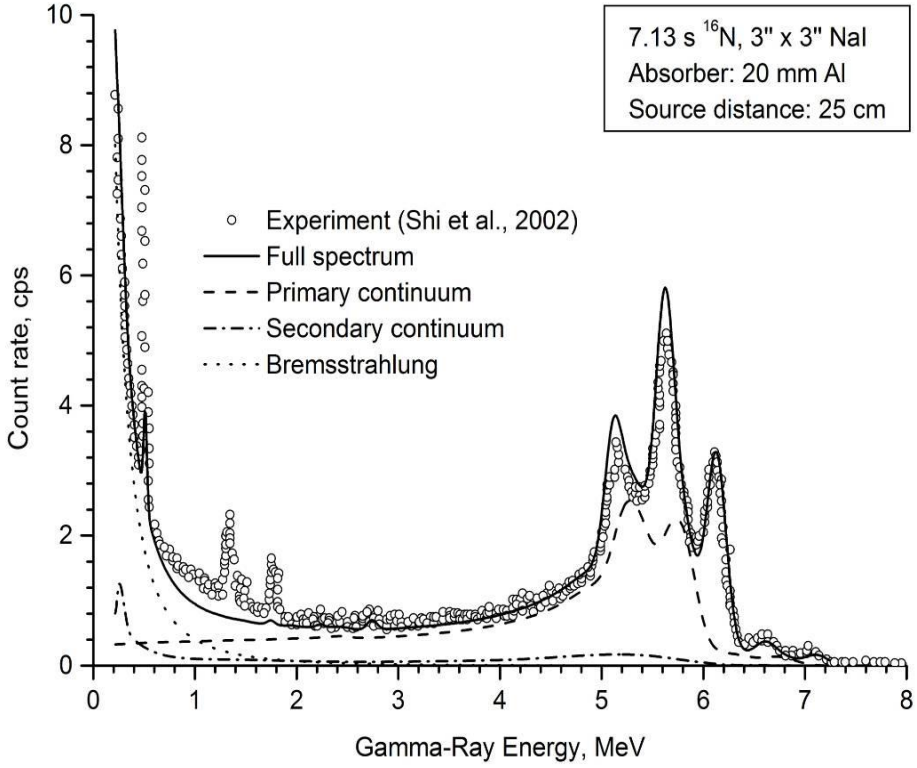
The experimental and simulated spectra for ^{137}Cs and a NaI 3″ × 3″ detector .

GSG in basic mode: Experimental validation (NaI)

Results of the experimental validation with 3″ × 3″ NaI scintillation detector



The experimental and simulated spectra for ^{24}Na and a NaI 3″ × 3″ detector.

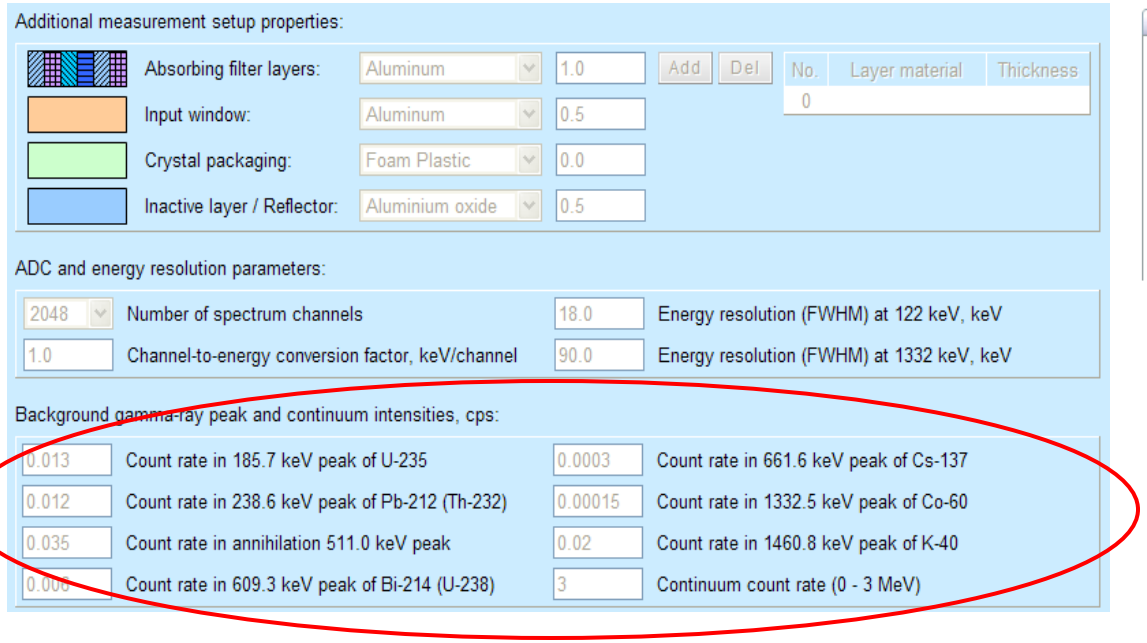


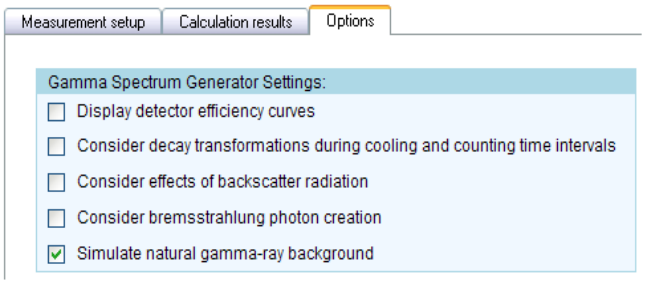
The experimental and simulated spectra for ^{16}N and a NaI 3″ × 3″ detector.

GSG-PRO: Additional modeling features

1. Modeling of a contribution from naturally occurring radionuclides (natural gamma radiation background)

Additional interface features:



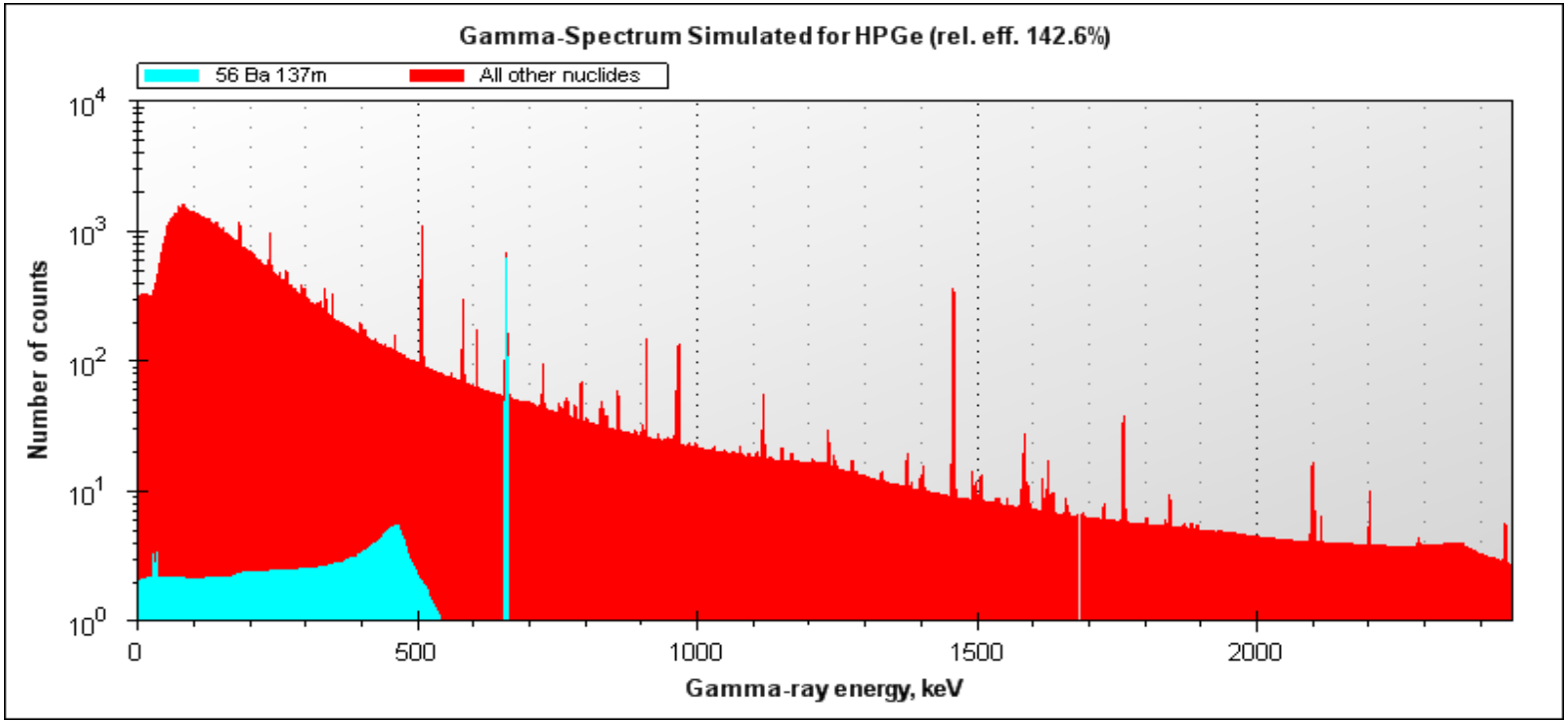


A respective option has to be selected on „Options“ tab to enable the background simulation

GSG-PRO: Additional modeling features

Example: low-activity / low-background measurements

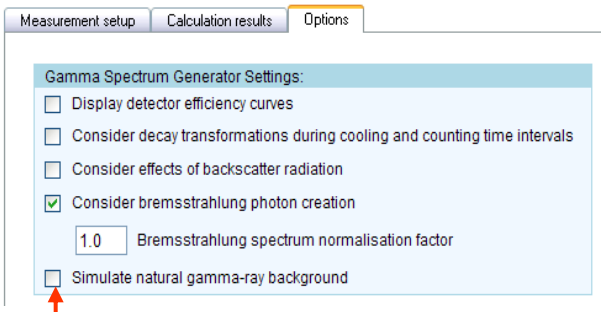
Inclusion of the background gammas results in a more realistic spectrum shape and MDA values, especially in low-activity measurements



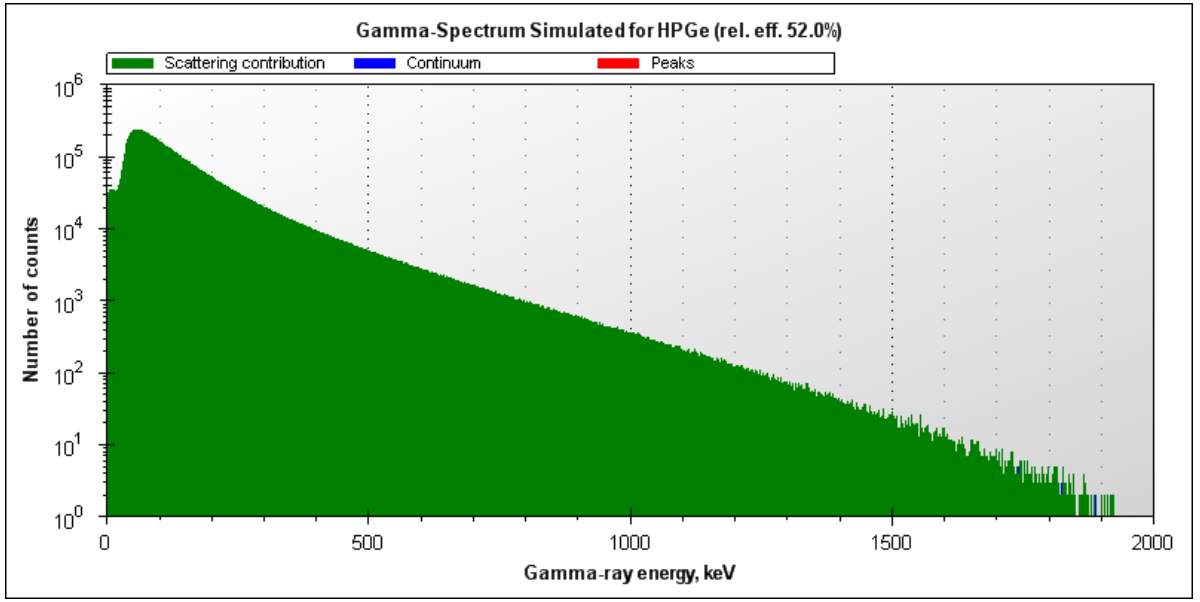
- A spectrum simulated for a 10 Bq ^{137}Cs source at the 10 mm distance from a 150% HPGe detector with natural background contribution included

GSG-PRO: Additional modeling features

2. Bremsstrahlung modeling option is available for beta-emitting nuclides:



A respective option must be selected on „Options“ tab to enable the bremsstrahlung simulation.



- A gamma-spectrum simulated for a 10 MBq ^{90}Sr-^{90}Y source and a 50% HPGe coaxial detector

Summary

- Gamma spectrum generator is a powerful tool for spectrum simulation
- Simulating spectra of arbitrary nuclides or nuclide mixtures
- Default and user-defined detector configurations (NaI, HPGe)
- Implemented in Nucleonica: point sources
- Educational and research tool

Exercises

1. Use the GSG to simulate the spectrum of a 3 kBq ^{60}Co source, taken for 1000 seconds at 25 cm from a 3”x3” NaI detector (default). Examine spectrum graph.
2. The same for a HPGe detector: coaxial, p-type, 50% rel. efficiency (default). Examine spectrum graph.
3. Simulate spectrum of ^{137}Cs, for the same HPGe configuration.
4. Optional: Simulate spectrum of a mixture, e.g., natural Uranium or ^{134}Cs+^{137}Cs.